

respectively. In formula (I-2), the conjugated, 5-membered cyclic ligands  $(C_5H_5-a-bR^8_b)$  and  $(C_5H_5-a-cR^9_c)$  may be the same or different ones.

$M^1$  represents a transition metal element of Groups 4 to 6 of the Periodic Table, including, for example, titanium, zirconium, hafnium, niobium, molybdenum, tungsten, etc. Of those, preferred are titanium, zirconium and hafnium, and more preferred is zirconium.  $Z^1$  represents a covalent-bonding ligand, including, for example, oxygen (-O-), sulfur (-S-), an alkoxy group having from 1 to 20, preferably from 1 to 10 carbon atoms, a thioalkoxy group having from 1 to 20, preferably from 1 to 12 carbon atoms, a nitrogen-containing hydrocarbon group having from 1 to 40, preferably from 1 to 18 carbon atoms, and a phosphorus-containing hydrocarbon group having from 1 to 40, preferably from 1 to 18 carbon atoms.  $X^1$  and  $Y^1$  each represent a covalent-bonding ligand, including, for example, a hydrogen atom, a halogen atom, a hydrocarbon group having from 1 to 20, preferably from 1 to 10 carbon atoms, an alkoxy group having from 1 to 20, preferably from 1 to 10 carbon atoms, an amino group, a phosphorus-containing hydrocarbon group having from 1 to 20, preferably from 1 to 12 carbon atoms (e.g., a diphenylphosphine group, etc.), a silicon-containing hydrocarbon group having from 1 to 20, preferably from 1 to 12 carbon atoms (e.g., a trimethylsilyl group, etc.), and a boron compound residue having a hydrocarbon group with from

1 to 20, preferably from 1 to 12 carbon atoms or having halogens (e.g.,  $B(C_6H_5)_4$ ,  $BF_4$ ). Of those, preferred are halogen atoms and hydrocarbon groups.  $X^1$  and  $Y^1$  may be the same or different, and they may be bonded to each other to form a cyclic structure.

In formula (4),  $M^1$  represents a transition metal of Groups 4 to 6 of the Periodic Table, such as that mentioned above; and  $X^1$  and  $Y^1$  have the same meanings as above. The meanings of  $X^1$  and  $Y^1$  shall apply to  $W^1$ . Namely,  $W^1$  is a covalent-bonding ligand, including, for example, a hydrogen atom, a halogen atom, a hydrocarbon group having from 1 to 20, preferably from 1 to 10 carbon atoms, an alkoxy group having from 1 to 20, preferably from 1 to 10 carbon atoms, an amino group, a phosphorus-containing hydrocarbon group having from 1 to 20, preferably from 1 to 12 carbon atoms (e.g., a diphenylphosphine group, etc.), a silicon-containing hydrocarbon group having from 1 to 20, preferably from 1 to 12 carbon atoms (e.g., a trimethylsilyl group, etc.), and a boron compound residue having a hydrocarbon group with from 1 to 20, preferably from 1 to 12 carbon atoms or having halogens (e.g.,  $B(C_6H_5)_4$ ,  $BF_4$ ). Of those, preferred are halogen atoms and hydrocarbon groups.  $X^1$ ,  $Y^1$  and  $W^1$  may be the same or different, and they may be bonded to each other to form a cyclic structure.

In formula (5),  $M^1$  represents a transition metal of Groups 4 to 6 of the Periodic Table, such as that mentioned

above; and  $X^1$ ,  $Y^1$  and  $W^1$  have the same meanings as above. The meanings of  $X^1$ ,  $Y^1$  and  $W^1$  shall apply to  $U^1$ . Namely,  $U^1$  is a covalent-bonding ligand, including, for example, a hydrogen atom, a halogen atom, a hydrocarbon group having from 1 to 20, preferably from 1 to 10 carbon atoms, an alkoxy group having from 1 to 20, preferably from 1 to 10 carbon atoms, an amino group, a phosphorus-containing hydrocarbon group having from 1 to 20, preferably from 1 to 12 carbon atoms (e.g., a diphenylphosphine group, etc.), a silicon-containing hydrocarbon group having from 1 to 20, preferably from 1 to 12 carbon atoms (e.g., a trimethylsilyl group, etc.), and a boron compound residue having a hydrocarbon group with from 1 to 20, preferably from 1 to 12 carbon atoms or having halogens (e.g.,  $B(C_6H_5)_4$ ,  $BF_4$ ). Of those, preferred are halogen atoms and hydrocarbon groups.  $X^1$ ,  $Y^1$ ,  $W^1$  and  $U^1$  may be the same or different, and they may be bonded to each other to form a cyclic structure.

(I) As specific examples of the transition metal compounds of formulae (2) and (3), mentioned are the following compounds. In the compounds to be mentioned below, titanium may be replaced with zirconium, and such zirconium compounds are also referred to herein to the same effect.

(1) Transition metal compounds not having a crosslinkable bonding group but having two conjugated, 5-membered cyclic ligands, such as